2002-2003
Annual Report

Montana Water Center

Serving the research and information needs of Montana's water-resource professionals.

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FROM THE DIRECTOR

As I write in early August 2003, wildfires, drying streams and falling reservoir levels are the norm throughout Montana. But drought is not our only water concern. Whether you're a Musselshell County homeowner worried about losing drinking water supplies this summer, a Prairie County sugar beet grower contemplating the possible impacts of coal-bed methane brines on your soil and water, or a Madison County fishing guide coping with the effects of whirling disease and fish habitat degradation, chances are that at least one issue of concern for you is a water issue.

The wet (actually average) winter and spring of 2002-2003 almost persuaded us that our drought was broken. Water experts knew better. Their repeated cautions that multi-year moisture deficits are not made up merely by one healthy precipitation cycle have helped prepare us for this dry summer. This is a good example of how good water science can fuel informed public policy and action.

Generating water knowledge and training water experts are the business of the Montana Water Center. Specifically, it is our charge to bring the brainpower of the Montana University System to bear on our state's water issues by sponsoring research, providing continuing education opportunities for water professionals, and educating future water professionals. This booklet is a summary of how we approached that challenge between July 2002 and June 2003.

Program Highlights

Fisheries Health: This year, we began transitioning the *Whirling Disease Initiative* into its final phase. Phase I concentrated on understanding the basic biology of the disease. The second phase explored the nuances of the disease's dependence on stream characteristics and its impacts on fish populations. The final phase of this program will focus on ecological risk assessment, testing of disease control methods, and technical assistance to fisheries managers. Whirling disease will never be eradicated, but seeking to curtail its spread and sustain salmonid fisheries in its presence is a reasonable and appropriate endeavor.

The *Wild Fish Habitat Initiative* is a new initiative this year funded

through the Partners for Fish and Wildlife Program of the U.S. Fish and Wildlife Service. Its goal is to evaluate methods that bolster wild fish populations in the northwestern U.S., and publicize the results among fishery and land managers. Five research/demonstration projects are now moving forward at sites in Montana, augmented by technical outreach materials for fishery managers. Key partners include fisheries scientists, managers, students, and private landowners.

We broadened the scope of our fisheries program this year by conducting the *7th International Symposium on Fish Physiology, Toxicology and Water Quality*. The symposium took place May 12-15, 2003, in Tallinn, Estonia, and drew 65 fisheries experts from sixteen nations. Though occurring nine time zones east of our state, this event addressed Montana water issues in two ways. First, Montana shares some of the basic pollution problems and effects discussed at the symposium. Second, this is an era when we're acutely susceptible to social upheaval elsewhere in the world. Since most humans derive most of their dietary protein from fish, it behooves us to share our expertise, and learn from others, to sustain healthy fisheries everywhere.

Drinking Water: Although it doesn't often hit the newspapers, I suspect that the most expensive water issues in recent Montana history involve providing drinking water and handling wastewater. Every community and rural household devotes considerable resources to these vital functions. Our *Technical Assistance Center for Small Public Water Systems* continues as the flagship of an eight-center national network. In the last two years we have serviced requests for more than 20,000 copies of our training materials for water treatment operators. Although we develop the training tools with the advice of Montana water operators to serve the needs of Montana systems, these tools are now used from Maine to Guam. The goal is the same everywhere: to provide technical training in a manner that is convenient and engaging, so that water treatment professionals undertake it with eagerness rather than dread.

Water Information: A great deal of our work entails making technical water information accessible to professionals. This year our *Non-Point Source Project Database* received praise from around the state. This is an Internet-accessible compendium of publicly-funded projects that abate pollution from diffuse sources such as construction and agriculture. If you're seeking to learn how much public money has been expended in, for example, the Sun River watershed, plus who managed the projects, what they did, and where to get copies of project reports, you'll appreciate this cyber-destination.

Montana Water Center Basics

This year our budget was approximately $1.8 million. The majority of our funding came as grants and cooperative agreements from eight local, state and federal agencies. Private-sector funding from the Cinnabar Foundation, the Steele Water Quality Endowment, and the Whirling Disease Foundation were also essential to Water Center efforts.

Early in 2003 we outfitted our media team with a substantial amount of new computer gear to support its development of cutting-edge training tools. At the same time the team moved into refurbished offices near our headquarters building. The tanks and aquaculture system components of the Wild Trout Research Laboratory also underwent a major upgrade and refitting.

We don't try to accomplish everything in-house. This year our staff of a dozen people oversaw 36 research and programming contracts. Our projects supported 24 graduate students and two undergraduates at Montana State University, Montana Tech, the University of Montana, and several out-of-state institutions. Soon these young scientists and engineers will be working water professionals, helping guide us through outbreaks of disease, pollution, and drought. The Montana Water Center is doing its best to equip them for the considerable challenges of their 21st-century careers.

Gretchen Rupp, Director
August 2003

The Montana University System Water Center, located at MSU-Bozeman, was established by the Water Resources Research Act of 1964. This act created and funded Water Resources Research institutes at land grant universities in 54 states and territories. The mission of the Montana Water Center is to mobilize the resources of Montana's public universities to resolve the state's water problems. It does this by sponsoring water-related research, providing training and education for current water professionals, and educating future water professionals.

WATER INFORMATION AND SERVICES

During FY 2003, the Montana Water Center developed or sponsored several tools and forums for distributing water information to those who need it.

Montana Water Website

The Water Center's web-based information transfer efforts include an expanded expertise directory, research projects database, Montana watersheds groups, events postings, a library checkout, and a clearing house for researchers, educators, agency personnel and watershed groups. You can view *Montana Water* at http://water.montana.edu. An electronic newsletter and a set of water resource forums hosted by the Montana Water Center will be unveiled in fall 2003.

Water Systems Teleconferences

The Water Center coordinates the Montana broadcasts of twice-yearly live teleconferences sponsored by the American Water Works Association. About 50 water-system professionals attend at downlink sites in Missoula, Havre, Great Falls, Billings, Helena, Butte and Bozeman. The November 2002 teleconference centered on emerging treatment technologies. In March 2003, participants learned the latest regarding water storage.

Blue Water Task Force

This citizen task force promotes public stewardship of aquatic resources in the Gallatin River Watershed through community education, citizen involvement in water quality monitoring, and scientific data collection. Each month, 15 active volunteers collect an array of water quality data at seven permanent locations along the river and two of its tributaries. Volunteers are also at work with local resource professionals to develop awareness programs on nonpoint source pollution and water conservation. These programs include a new water quality curriculum at Ophir School in Big Sky, Montana, and the publication of Task Force articles in a Big Sky newspaper. The Montana Water Center lends technical expertise, laboratory facilities, and coordination for data collection and outreach efforts. Efforts are underway to establish the Task Force as an independent group within the community of Big Sky through support from small grants and a new advisory board. Find out more at http://water.montana.edu/bwtf.

69th Annual Water School

Nearly seven decades of excellent training for water and wastewater operators and managers has been offered by the "Water School." Each year, operators from throughout Montana can receive four days of training for managing their local systems. The program features workshops and presenters from private consulting, industry, academia and government. At the close of the training, operators may sit for the water/wastewater certification exam administered by the Montana Department of Environmental Quality (DEQ). Along with DEQ, this program is conducted by the Montana Environmental Training Center, the Montana Water Center, and the MSU Civil Engineering Department.

19th Annual Montana Water Conference

With the Montana Section of the American Water Resources Association, the Water Center each year organizes the Montana Water Conference. This year the conference was held in Livingston, Montana with a focus on the future of the Upper Yellowstone River. Serving a record number of attendees, the two-day meeting included about 30 papers and 10 posters. This meeting is anticipated each year by water professionals from throughout Montana who share information on research methodologies, issues, challenges, and successes. A web-based archive of AWRA's Montana Chapter activities and meetings is found at http://www.awra.org/state/montana/.

AWRA
American Water Resources Association
Montana Section

Kids' Fishing Derby

As part of National Fishing Week in June, the Bozeman Fish Technology Center hosted the 13th Annual Bozeman FTC Kids' Fishing Derby. Children aged 6 years and under were invited to catch two trout from the Center's well-stocked pond. Nearly 2,500 people attended, including 848 kids who fished. Children, parents, and grandparents were treated to a fun and exciting day of fishing, games, prizes, and photo opportunities. The Water Center has participated in this event since 1997; this year's donation included refreshments and the fish-cleaning talents of our Wild Trout Lab Manager, Cal Fraser.

Ecosystem Restoration Website

Few places remain where human activity has not altered the function of endemic ecosystems. A century ago little consideration was given to the return of disturbed land to a natural state, yet today environmental quality is a societal priority. This website is committed to that priority and to the technical challenge of achieving ecological restoration. Its goal is to provide ecological restoration tools to designers, managers and practitioners in a web-based information repository. Contained within the site are case histories, images, educational guides, and links to literature and supporting websites. The site can be accessed at http://ecorestoration.montana.edu.

USGS WATER RESEARCH PROJECTS AND PROFILES

The U. S. Geological Survey's 104(b) program addresses a spectrum of state water problems with its research funds. Guided annually by our Water Resources Research Advisory Committee, Montana investigators and graduate students study issues like groundwater contamination, post-fire soil erosion, and runoff dynamics. The Advisory Committee identifies research priorities, oversees peer review of proposals, and recommends projects for funding. About $55,000 is available for award to Montana investigators each year. You can find full reports at: http://water.montana.edu/topics/research/projects/.

Projects Ongoing or Completed in 2003

Quantitative assessment of the effectiveness of post-fire erosion control techniques. Scott Woods and Thomas DeLuca, University of Montana.

This study evaluates the effectiveness of three commonly-used hillslope erosion control treatments: straw wattles, mulching and aerial seeding, for reducing post-fire erosion rates. Two areas of Montana affected by forest fires in 2001 and 2002 serve as study sites. One experiment is assessing the effectiveness of straw wattle installation and mulching in reducing post-fire erosion rates from hillslope plots exposed to natural rainfall. A second experiment assesses the effectiveness of aerial seeding and mulching in reducing post-fire erosion from small plots exposed to simulated rainfall. Another study is looking at effectiveness of aerial seeding in reducing erosion rates from hillslope plots exposed

to natural rainfall. These data will help land managers select more efficient erosion control treatments, thus helping to reduce the costs associated with mitigating forest fire effects.

Pharmaceuticals in septic system effluent. William Woessner and Garon Smith, University of Montana. This project studies the potential for individual septic systems to load shallow groundwater with trace amounts of pharmaceuticals and metabolites. It will: 1) develop analytical procedures for identifying and quantifying target pharmaceuticals in septic systems using high performance liquid chromatography coupled with mass spectrometry; 2) determine the probability of occurrence of targeted compounds in individual septic system effluent; 3) examine fate of selected compounds during transport through soils; and 4) suggest the fate of selected compounds in groundwater systems. The first phase of study has developed techniques to detect the six target pharmaceuticals to sub-part-per-billion levels.

Recharge assessment of the Anaconda Mine near Belt, Montana. Jon Reiten, Montana Bureau of Mines and Geology. Decades of underground coal mining have resulted in acid mine drainage which has contaminated groundwater and surface-water resources in Belt, Montana. The acid mine drainage is lowering the pH of Belt Creek and increasing trace metals concentration in the stream. The goal of this project is to define the hydrogeologic regime in the vicinity of Belt so that recharge associated with old mine workings and the source of acid mine drainage can be delineated with certainty.

Groundwater recharge characterization using isotope and geochemical analyses, West Billings area, Yellowstone County, Montana. John Olson and Jon Reiten, Montana Bureau of Mines and Geology. This investigation evaluated the potential impacts of urban and suburban development in the West Billings area on the Yellowstone River alluvial aquifer and surface-water systems. Results suggest that groundwater recharge rates and surface-water quality are linked, and that over time, current levels of development and lowering of groundwater levels will lead to a continued deterioration in water quality.

MTBE biobarriers in stream sediments. Elsa Meiser and Joel Cahoon, Montana State University. Methyl *tert*-Butyl Ether (MTBE) is a fuel oxygenate added to gasoline to boost octane and reduce carbon monoxide emissions. This study investigated the use of the Michaelis-Menton and Hill mathematical models to describe the dependence of MTBE degradation by a bacterial isolate on dissolved oxygen concentration. It was found by regression analysis that the Hill model better represents the situation at a contaminated site in Lake County, Montana.

RESEARCH PROFILE

Jon Reiten is looking for pieces to the acid mine drainage puzzle

In what started out as a seed project for research of a much grander scale, hydrogeologist Jon Reiten from the Montana Bureau of Mines and Geology in Billings embarked on a fascinating study. He began working to pinpoint the source of recharge to 50-year-old mine workings, the source of serious acid mine drainage in Belt, Montana. The idea came from a research team member, Shawn Reddish (student then, professional geologist now), who wanted to learn why the fish were dying and acid mine drainage increasing in her hometown Belt swimming hole.
Now the team is inventorying wells in the 30-square-mile study area. By

age dating groundwater, the recharge source entering the mine may be determined, with the ultimate goal of reducing non-point pollution, improving stream habitat, and restoring groundwater and surface water quality. Hydrogeologic data and water-quality information will be used to calculate changes in recharge and groundwater flow rates, as well as acid mine drainage discharges under various scenarios and combinations of cropping, dewatering, and other techniques.

The Water Center's seed funds for Reiten's work have leveraged support from other agencies, along with furnishing a training ground and mentorship for new professionals learning to solve complex water problems. Reiten is expanding the study to include 3-D geologic modeling of the mine itself, along with satellite coverage and remote sensing of the entire study area. "This is a very interesting problem and project. It's opened our eyes to observing abnormally wet areas above mines as sources of vertical recharge, " says Reiten. More information on this study is found at http://water.montana.edu/topics/research/projects.

Projects Initiated in 2003

Understanding and predicting changes in the microbial ecology of mine tailings in response to the addition of dissolved organic carbon. Paul Sturman, Montana State University. This research is predicting the response of iron-oxidizing and sulfate-reducing microbial populations to various organic carbon addition strategies. Results will help field engineers select the most appropriate sources of organic carbon for field application to mine tailings as well as provide tools for assessing the microbial condition of mine wastes prior to implementing a solution, and after a treatment is applied. Although remedial measures that rely on microbially-catalyzed reactions are in common use, we currently lack the tools to predict and measure responses of important microbial populations.

Potamopygrus antipodarum *and Baetid mayflies: temporal variation and community-level consequences. Billie Kerans, Montana State University.* This study investigates the consequences of the New Zealand mud snail (*Potamopyrus antipodarum)* introduction on other macroinvertebrate populations. The mud snail's increasingly higher densities, plus its feeding ecology and reproductive biology suggest that it could compete with other grazing macroinvertebrates, affecting the availability of food for Montana fish.

Topography, groundwater dynamics, and soil frost: first-order controls on snowmelt runoff dynamics and plant species distributions across an upland-wetland transition. Brian McGlynn, Montana State Univeristy. This project studies the controls on snowmelt flow pathways, frost depth, and plant species distributions across an upland–wetland transition. It is a first step in the development of a conceptual model of snowmelt flowpaths and hydro-ecologic dynamics at the landscape scale. The hydrologic dynamics and plant species distributions appear tightly linked at Red Rock Lakes in the Centennial Valley, making this an ideal site for new investigation in the emerging field of hydroecology.

Intern Program

A training ground for incoming professionals keeps water science vital. In keeping with one of the most important elements of the Montana Water Center mission, we provide opportunities for undergraduate interns to mentor with the U.S. Geological Survey in field training positions. This year, intern Kyle Griffith worked with USGS hydrologists in Helena.

SMALL DRINKING WATER SYSTEMS TECHNICAL ASSISTANCE

The Montana Water Center operates the flagship institution of an eight-center network of Small System Technology Assistance Centers. Funded by the U.S. Environmental Protection Agency (EPA), the centers work to protect public health, improve water system sustainability, and enhance regulatory compliance by small water systems. The centers apply university resources to address the needs of rural and small public water systems or public water systems that serve Indian tribes, in the areas of technology verification, testing of innovative technologies, and training and technical assistance. Project descriptions and resources from all eight Technical Assistance Centers can be accessed on the TACnet website maintained by the Montana Water Center: http://water.montana.edu/tacnet/.

Research and Assessment (two grants totaled $190,000 in 2003)
Centrally-managed point-of-use treatment. Charles Moretti, Department of Civil Engineering, University of North Dakota. This project evaluated point-of-use reverse osmosis (POU-RO) to remove arsenic

from groundwater supplies for small communities. This approach has only recently become permissible, and there are still many questions about its feasibility and acceptance. Two commercially-available POU-RO systems were tested in the laboratory to determine how well they remove arsenic from water. Next, a pilot test was conducted in a small community water system that will have difficulty meeting the new standard for arsenic in drinking water. POU-RO systems were installed in 21 homes and public buildings, and then monitored for arsenic removal. Questions about the management, maintenance, monitoring, and cost of POU systems are addressed in the project report.

Toolbox to assess system microbial risk. Phillip Butterfield and Anne Camper, Center for Biofilm Engineering, Montana State University. This project fosters technical and managerial capacity in small water systems drawing from springs, wells, surface waters or any combination of sources. This computational tool, an interactive spreadsheet application, helps small water systems assess their vulnerability to microbial contamination. System personnel are led through a series of questions based on their water sources and treatment/distribution trains. When the questioning is completed, the program ranks system components and their relative vulnerabilities, with interpretation and suggestions for abating the vulnerability. The user can test the results of various actions using the tool before expending the capital to make changes in the real system.

Training Tools

Operator Basics. The Center provides tools for small public water system operators and technical assistance providers throughout the United States. The core project is the Operator Basics Training Series.

This year, our programming team developed the latest module of the series -- *Groundwater Systems: National Version 2003*. It is available online, as a hard-copy document, and as a download that can be installed directly to users' computers. An industry first, our approach is

to provide operators and managers of small public groundwater systems with challenging, colorful, and fun interactive activities that offer working knowledge of small public groundwater system operations.

As of August 2003, about 8,000 copies of the 2003 version had been distributed by the National Drinking Water Clearinghouse. Total distribution to date is 18,000 CDs along with thousands of downloads from our website. Up to 13.5 hours of training can be documented by working through all 11 units of Groundwater Basics 2003. The program also offers chances to sharpen math skills with animated water-related problems and solutions, as well as a listing of operator contacts for every state and EPA region. Find more at http://water.montana.edu/training/

Sanitary Survey Fundamentals. This interactive tutorial provides the basics on public water systems, a specialized vocabulary, and better understanding of the in-depth Sanitary Survey workshops given by EPA's Drinking Water Academy and other organizations. The EPA funded the Montana Water Center to produce this interactive CD-ROM , and its Drinking Water Academy helped with the content layout and review process. We've incorporated 3D fly-ins, animation, interactivity, games, narration, and video into this tool, all without the need for users to install a plug-in. The course takes about two hours to complete. This year, 2000 CD-ROMs were produced for national distribution. Free copies can be ordered by calling the Drinking Water Clearinghouse at 800-624-8301. Refer to the Sanitary Survey Fundamentals Prep Course, product #DWCDTR19. The 153 MB program can be downloaded at: http://water.montana.edu/training/ssf.

FISHERIES HEALTH

2001-2002 Whirling Disease Research

The Whirling Disease Initiative is overseen by the National Partnership for the Management of Wild and Native Coldwater Fisheries, a national advisory team coordinated through the Montana Water Center. Each year, the Partnership's Whirling Disease Steering Committee reviews an impressive set of research proposals, choosing those that will effectively address high-priority whirling disease research needs. The Partnership can allocate up to $590,000 of federal dollars annually for whirling disease research.

Effects of* Myxobolus cerebralis *infection on Chinook salmon and steelhead trout in northeastern Oregon. Jerri Bartholomew and Paul W. Reno, Oregon State University. This project assessed the susceptibility of Chinook salmon to the whirling disease parasite, *Myxobolus cerebralis,* and examined current management practices for anadromous salmon that may lead to parasite exposure. Laboratory challenges demonstrated infection severity is lower and disease resistance develops earlier in Chinook salmon than in the rainbow trout. It was also found that exposure of anadromous salmonids to *M. cerebralis* may also contribute to the dissemination of the parasite. Exposures of sentinel rainbow trout demonstrated presence of the parasite at all acclimation sites, but infection in steelhead smolts demonstrated that infection occurs even when exposure is delayed until one year of age. Further, infected fish from eastern Oregon have been detected as adults straying into lower Columbia River tributaries, suggesting that these fish may interfere with management efforts to prevent the spread of *M. cerebralis*. Finally, transfer of naturally-exposed and experimentally-challenged steelhead to salt water demonstrated a decreased ability to survive, suggesting that *M. cerebralis* infection may contribute to mortality during saltwater adaptation.

Application of DNA-based genetic markers to determine difference in susceptible and non-susceptible* Tubifex tubifex *populations to* Myxobolus cerebralis *from the upper Colorado River and Windy Gap Reservoir. Katherine A. Beauchamp and Ronald P. Hedrick, University of California at Davis; and R. Barry Nehring, Colorado Division of Wildlife. The investigators examined the geographic distribution of *Tubifex*

tubifex (the alternative host of the whirling disease parasite), by genetic screening at 20 sites above, below and within the Windy Gap Reservoir on the upper Colorado River. The sites varied with respect to land and water use practices and represented habitats that were presumed to be more or less conducive to oligochaete abundance and diversity and where impacts of whirling disease on rainbow trout were considered high, moderate or low. Results suggest that the distribution of various genotypes of *T. tubifex* are one important factor in determining whether rainbow trout in specific aquatic environments will be more apt to experience severe effects of whirling disease. Sites with a greater abundance of *T. tubifex* from *M. cerebralis*-resistant lineages may prevent the parasite from reaching concentrations where rainbow trout population impacts occur.

The effect of chemical control of Tubifex tubifex *on the incidence of whirling disease in Colorado hatcheries. Eric P. Bergersen, Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University; Dan Kowalski, Colorado State University.* This study assessed two common pesticides, Bayluscide and TFM, as chemical controls of *T. tubifex*, examined intraspecific differences in toxicity, and made recommendations on the possibility of chemical worm control. Worms susceptible to *M. cerebralis* infection were more sensitive to both chemicals than worms resistant to the parasite in the toxicity tests. The toxicity differences of exposed and unexposed worms within a lineage were not as great as between lineages. Due to the rapid degradation, relatively selective toxicity, cost, and regulatory status, Bayluscide appears to be the best candidate for further study as a chemical control of the oligochaete host of the parasite.

Ecological differentiation and survivability of Tubifex tubifex *infested with* Myxobolus cerebralis *in the San Juan River, New Mexico tailwater "Blue-Ribbon" trout fishery. Colleen Caldwell and Robert DuBey, New Mexico State University.* This first part of a two-year study established and characterized the distribution and environmental constraints of genetic variants of *T. tubifex* within the San Juan River tailwater near Navajo Dam, New Mexico. Sixty benthic and sediment samples collected in 2001 were processed to establish tubificid density, community structure, and the percentage of *T. tubifex* within each population. The percentage of *T. tubifex* within the enumerated samples ranged from 1 to 96 percent. Parasite screening for whirling disease showed infection rates ranging from 0 to 15 percent within the sample reach, with higher percentages in samples from deep habitat. Three genetic lineages of *T. tubifex* were identified, and *T. tubifex* lineage monocultures are now being established to experimentally explore the survivability of

encysted *T. tubifex* as well as the post-treatment viability of *M. cerebralis* spores under controlled temporal and thermal regimes.

Rapid identification of immature and mature Tubifex tubifex *by monoclonal antibodies. Donald W. Roberts and Nabil N. Youssef, Utah State University.* Most of the year it is impossible to identify an aquatic worm as *T. Tubifex* using conventional microscopy. In this project the investigators developed monoclonal antibodies (MAbs) to identify *T. tubifex*. Each MAb is produced by a tissue culture cell line derived from a single spleen cell from mice that have been injected with the proteins from the worm of interest. The investigators isolated hybridoma cell lines which produce antibodies specific for *T. tubifex* and *Rhyacodrilus*, another aquatic worm found in similar habitats. MAbs made to one geographical isolate of *T. tubifex* recognize *T. tubifex* ranging from Ontario to California. Contingent on further funding, twelve anti *T. tubifex* MAbs will be evaluated to determine which will function most effectively for worm identification in the laboratory and field.

Mechanisms of resistance to Myxobolus cerebralis *infection in brown trout, cutthroat trout and coho salmon in comparison to the highly susceptible rainbow trout. Ronald P. Hedrick and Mark A. Adkison, University of California at Davis.* The investigators used scanning electron microscopy to compare the number of triactinomyxons (TAMs) that attach in the first 10 minutes of exposure to rainbow trout, westslope cutthroat trout, brown trout and coho salmon. They also used histology and light microscopy to determine the number of sporoplasm somatic cells that successfully migrated into the epithelium one hour after attachment of the TAMs. Data indicate that the resistance of coho salmon and brown trout to whirling disease is conferred by different immune mechanisms. Coho salmon prevent infection by inhibiting the migration of most of the sporoplasm somatic cells into the epithelium, ultimately resulting in a light infection. In brown trout the parasite successfully invades and becomes established in the epithelium. At some point between the epithelium and the cartilage, the immune response engages and significantly reduces parasite numbers. Resistance in westslope cutthroat, although much less strong, may be due to similar mechanisms as seen in the coho salmon.

Epidemiology of whirling disease: An integrated study of the Rock Creek drainage, Montana. Willard O. Granath, Jr., University of Montana; Eric Reiland, Montana Fish, Wildlife, and Parks; Billie L. Kerans, Montana State University; and Charlotte Rasmussen, Western Fisheries Research Center. In Rock Creek, western Montana, results of a four-year project indicate that infected *T. tubifex* are present in much

greater numbers and are more widely dispersed in areas with degraded riparian habitat. However, trout become infected at many locations where infected *T. tubifex* have not been recovered, and it is possible that fish are infected by parasites originating hundreds or thousands of meters upstream. It also appears that the range of whirling disease within the Rock Creek drainage is still expanding, more than four years after its initial detection. Total water flow appears to affect the severity of disease; an apparent dilution effect on parasites was observed in the upper portion of the drainage. Genetic analysis indicated the presence of at least three distinct genotypes of *T. tubifex* within the Rock Creek drainage and all three are susceptible to infection.

Competitive effects of tubificid assemblages on triactinomyxon production of Tubifex tubifex. *Billie L. Kerans, Montana State University, and Charlotte Rasmussen, Western Fisheries Research Station.* The goal was to determine mechanisms underlying spatial variability in salmonid whirling disease risk that relate to tubificid assemblages, in order to develop potential management strategies for combatting disease. Researchers have found that the prevalence of infection in *T. tubifex* is density-dependent: the higher the abundance of *T. tubifex*, the lower the prevalence of infection. The investigators observed that as myxospore dose increased from 10 to 100 per worm, the prevalence of infection in *T. tubifex* increased. Prevalence of infection in *T. tubifex* and numbers of parasites produced by individuals appeared to be minimally affected by the presence of the aquatic oligochaete *Limnodrilus hoffmeisteri*, which does not sustain the whirling disease infection. Finally, the presence of resistant *T. tubifex* may decrease the numbers of TAMs (the infective form of the parasite) produced by susceptible *T. tubifex* early in the release process.

Prevalence and severity of Myxobolus cerebralis *infection related to water temperature and flow regimes of native cutthroat trout,* Oncorynchus clarki bouvieri*, in spawning tributaries of Yellowstone Lake. Todd Koel, National Park Service; and Crystal Hudson, U. S. Fish and Wildlife Service.* The goal was to define the relationship between temperature and streamflow in the Yellowstone cutthroat trout spawning tributaries to Yellowstone Lake, and the rate and intensity of whirling disease infections. These activities were to characterize physical habitat in 13 diverse streams, characterize the distribution of *T. tubifex* in the streams, and expose cutthroat trout there to ascertain whirling disease virulence. Moderate to high infections by *M. cerebralis* were found in Pelican Creek and the Yellowstone River below Fishing Bridge. No other tributaries tested positive for the disease. Laboratory testing of

adult cutthroat trout that are incidentally killed during lake trout gillnetting operations continues to indicate the presence of *M. cerebralis* lakewide, with the greatest numbers (19%) infected in the northern region of the lake. There is a high risk of infection in additional tributaries to Yellowstone Lake. Analyses of landscape-scale environmental attributes suggest that Beaverdam Creek, Trail Creek, and Chipmunk Creek are likely candidates for supporting the spread of this parasite.

Demonstration and evaluation of alternative methods of filtering triactinomyxons of Myxobolus cerebralis *for control of whirling disease. Eric Krch, Buckhorn Geotech, Inc. and R. Barry Nehring, Colorado Division of Wildlife.* This study determined the feasibility of direct filtration for removal of *Myxobolus cerebralis* parasites in various filtration media. Bench testing and field demonstrations were conducted using domestic and natural water sources to develop a scope of considerations and evaluate filtration media types. Field results suggest that direct passive filtration is possible; however, operation and maintenance are crucial elements in full-scale operations. The study recommends design considerations, filtration media selection, and application rates of infected influent to achieve desired rates of *M. cerebralis* removal.

Interaction of life history, fish size, and infection risk on population-level effects of whirling disease on wild rainbow trout. Thomas E. McMahon, Alexander V. Zale, and Andrew Munro, Montana State University; and Stephen A. Leathe and George Liknes, Montana Fish, Wildlife & Parks. This study on the Missouri River in Montana combines monitoring of infection spread with detailed measures of population response to the disease. The investigators tested whether spawning and rearing in disease-free areas is a viable management option for maintaining and enhancing trout populations in infected systems. Rainbow trout populations remained high and did not drop as a result of whirling disease. However, there are signs of impending population decline as the remaining adults near the end of their life span and the size structure of the adult population shows a much-reduced number of younger fish than in pre-whirling disease years. Expansion of whirling disease into lower tributaries, while not observed to a great degree thus far, could have catastrophic consequences since it appears that most of the adult population is supported by recruitment from these tributaries.

Development of empirical models of Myxobolus cerebralis *to predict risks for populations of fish across river drainages. Christine M. Moffitt, University of Idaho; Keith Johnson, Idaho Fish and Game; and Bruce Rieman, U.S. Forest Service.* Investigators developed empirical models that describe both population dynamics and landscape-level factors

associated with the prevalence, intensity of infection, and likelihood of risk to fish populations of *Myxobolus cerebralis*. They created a simple dynamic disease model for *M. cerebralis,* a discrete compartmental model to explain the course of disease in both fish and worms. They drafted a landscape-level model that incorporate GIS-based information extracted from digital maps. This model uses three landscape attributes: channel slope, catchment area, and elevation which can indirectly affect the intensity of infections. This project continues to refine the empirical models, to add other landscape level metrics, and to improve the manner in which geospatial data are collected from digital maps.

Characterization of the response of genetically distinct Tubifex tubifex *populations to* M. cerebralis *infection in laboratory and natural systems. Charlotte Rasmussen, James R. Winton, and Alison E. L. Colwell, Western Fisheries Research Center; and Billie L. Kerans, Montana State University.* Results suggest there are four genetically-distinct clades of *Tubifex tubifex* in this system. The two groups of worms showing high and moderate parasite production may comprise one large related group, while the remaining two clades consist of low producers and non-producers. Field studies to determine the genetic composition of naturally-occurring *T. tubifex* populations were expanded. Genetic analysis from several streams in Montana indicates that these populations consist of individuals with moderate to high parasite production, which is consistent with the disease epidemiology seen on these river systems.

2002-2003 Whirling Disease Research

Temporal analysis of immunity to Myxobolus cerebralis *in resistant and susceptible species using real-time taqman quantitative PCR to track replication of the parasite in the fish. Mark A. Adkison and Ronald P. Hedrick, University of California-Davis.* The researchers anticipate detecting differences in parasite replication in the skin, nerves, and cartilage of resistant and susceptible salmonid species. The resistant species are brown trout, coho salmon, some strains of cutthroat trout, and the German Hofer strain of rainbow, while most strains of rainbow trout are very susceptible. Using TaqMan PCR technology to track replication in different areas in the resistant and susceptible species, the researchers will have a greater chance to identify the specific immune components responsible for resistance.

Effects of Myxobolus cerebralis *infection on Chinook salmon and steelhead trout in northeastern Oregon. Jerri L. Bartholomew, Oregon State University and Paul W. Reno, Hatfield Marine Science Center.* This project expands previous work done in northeastern Oregon to exam-

ine the effects of *Myxobolus cerebralis* on managed populations of steelhead. The researchers are examining the incidence of infection among steelhead exposed to *M. cerebralis* during acclimation at Wallowa Hatchery to determine the effect of salt water on *M. cerebralis* infection in steelhead.

Effects of spring creek rehabilitation on infection rates of whirling disease in trout. Patrick Byorth, Montana Fish, Wildlife and Parks. This project examines the effects of rehabilitating two Montana spring creeks on whirling disease severity in these creeks. The researcher will determine presence or absence of whirling disease in the creeks, infection rates before habitat enhancement, and infection rates one year after enhancement.

A quantitative PCR (QPCR) approach to rapidly distinguish between Myxobolus species *and assess infection severity in fish. Ken Cain, University of Idaho; Keith Johnson, Idaho Department of Fish and Game; Matt Powel and Ken Overturf, Idaho Hagerman Fish Culture Experiment Station; and John Wood, Pisces Molecular, Inc.* This project will produce a new diagnostic tool (QPCR) which will rapidly confirm *Myxobolus cerebralis* and quantify infection severity in fish. This will be a quantitative real-time PCR analysis that correlates to histological scoring or spore counts. The researchers will also develop species-specific probes that will identify other closely-related *Myxobolus* parasite species.

Ecological differentiation and survivability of Tubifex tubifex *infested with* Myxobolus cerebralis *in the San Juan River tailwater, New Mexico. Colleen Caldwell and Robert DuBey New Mexico State University.* A continuation of work begun in 2001, this project will relate *Tubifex tubifex* lineage genetic variation to trophic conditions. It is also establishing cloned monocultures of lineage-specific *T. tubifex* from differentiated habitats in the San Juan tailwater to explore survivability of lineage and habitat-specific *T. tubifex*. The viability of *M. cerebralis* infection under varying environmental conditions is also under study.

RESEARCH PROFILE

Parasitologist finds "perfect" research project in Rock Creek

Ask Bill Granath of the University of Montana how he got involved in his five-year study of the ecology of whirling disease in Rock Creek, Montana, and he'll tell you it was a combination of his deep professional interest in parasites, a love of fly fishing, and perfect timing when whirling disease hit hard in Montana's wild trout streams.

Granath received his PhD in Parasitology in 1982 and just happened to focus his doctoral work on a fish parasite, *Schistosoma*. When the federal funds became available from the Partnership in 1996 for rapid response solutions to the whirling disease dilemma, the fact that the causative parasite had a two host life cycle had only just been discovered. Granath thought it a critical time to begin a long-term study of a parasite throughout an entire drainage. An uplifting part of this work, he says, was that "local people and other scientists would listen to what I was trying to do and offer great ideas and insights. This was a breakthrough for real decisionmaking. I felt like my research was making a difference."

Indeed it has. He and his team of five graduate students who have assisted and benefited from this research have found that the whirling disease parasite is not uniformly spread in the basin. "Hotspots," where the parasite prevails, are areas deserving of more management focus, like concentrated habitat restoration. Now Granath and his team are busy testing the degree to which watershed management practices like habitat restoration and streamflow variation influence disease severity.

Epidemiology of Whirling Disease: An Integrated Study of the Rock Creek Drainage, Montana. Willard O. Granath, Jr. and Michael Gilbert, University of Montana; Billie L. Kerans, Montana State University; and Eric Reiland, Montana Fish, Wildlife and Parks. This project continues work initiated in 1998 in Montana's Rock Creek drainage. It will determine percentages of *Tubifex tubifex* releasing *Myxobolus cerebralis* in Rock Creek, determine seasonality of parasite release, monitor intensity of infection of disease in trout, determine effects of water flow and habitat restoration on epidemiology of whirling disease, and examine genetic heterogeneity of *T. tubifex* in Rock Creek.

Relating Myxobolus cerebralis *infection in native Yellowstone cutthroat trout and* Tubifex tubifex *with environmental gradients at multiple spatial scales. Billie L. Kerans, Montana State University; Todd M. Koel, National Park Service; and Charlotte Rasmussen, Western Fisheries Research Station.* This project examines Yellowstone Cutthroat trout (YCT) populations in Yellowstone River, Pelican Creek, and Clear Creek within Yellowstone Park. The investigators are examining whirling disease infection risk as it relates to tubificid assemblages, prevalence of infection in tubificids, spore loading in adult spawning YCT, physical and chemical features of the watercourses chosen, and life history patterns of YCT.

Demonstration and evaluation of wetlands treatment for Myxobolus cerebralis *actinospore attenuation. Eric Krch Buckhorn Geotech, Inc., Colorado.* This project looks at the possibility of using artificial subsurface flow treatment wetlands to remove the whirling disease parasite from an infected water source.

Development of empirical models of Myxobolus cerebralis *to predict risks for populations of fish across river drainages. Christine M. Moffitt, University of Idaho; Keith Johnson, Idaho Fish and Game; and Bruce Rieman, USDA Forest Service.* This study continues to develop mathematical models that describe the relationships of *Myxobolus cerebralis* in fish and *Tubifex* worm populations. Investigators are defining landscape parameters associated with historical data records of free ranging fish in Idaho, Montana, and other states. Their goal is to generate a model describing the probability of infection by *M. cerebralis* in a selected area, based on map-level landscape characteristics.

Determination of the infection efficiency of myxospores and TAM stages of Myxobolus cerebralis *infection and a laboratory model of the entire Infectious cycle. Paul W. Reno, Oregon State University.* This project explores the entire life history of *Myxobolus cerebralis* in the

laboratory under conditions that simulate the natural environment. Research thus far has tested the disease under laboratory conditions which are not consistent with many variables found in nature. Here, the researcher is using simulated natural environments to assess risk of disease transmission in natural populations.

Evaluating the efficacy of physical habitat modification to reduce the impacts of Myxobolus cerebralis *infection in streams. Kevin G. Thompson, Colorado Division of Wildlife.* The first phase of this study is to rebuild irrigation diversions on two sections of the Williams Fork River in Colorado and identify an appropriate control reach. The rebuilt structures will function as irrigation diversions but discourage the accumulation of fine sediment and organic debris. The investigators will then determine if less sediment and organic debris is released into the system, and whether that reduces *Tubifex tubifex* populations, parasite release, and disease severity.

Temporal, spatial, and discharge- mediated dynamics of triactinomyxon abundances and infection risk estimated directly by packed-bed filtration. Alexander V. Zale, Montana Cooperative Fisheries Research Unit and Frederic T. Barrows, Bozeman Fish Technology Center, USFWS. The TAM-O-METER project is a continuation of earlier work in which researchers developed an apparatus and methodology to directly enumerate triactinomyxons (TAMs) from an experimental water source. This project tests the device and methodology on natural rivers using sentinel-fish cages.

7th International Symposium on Fish Physiology, Toxicology and Water Quality

This symposium series was initiated in 1988 as a scientific collaboration between the governments of the United States and the People's Republic of China. Since then, symposia have been held throughout the world and have involved scientists from more than 25 nations. The Seventh Symposium, organized by the Montana Water Center, convened on the shores of the Baltic Sea in Tallinn, Estonia. Scientists and students from sixteen nations gathered to discuss work related to eutrophication and hypoxia, as they affect both freshwater and marine fishes. Manuscripts from the symposium will be published in a proceedings in 2004. Symposium sponsors included the EPA, the Estonian Academy of Sciences, the Estonian Agricultural University, the International Section of the American Fisheries Society and Montana State University.

Wild Fish Habitat Initiative

The purpose of the Wild Fish Habitat Initiative is to enhance the success of riparian projects conducted through the Partners for Fish and Wildlife Program, administered by the U.S. Fish and Wildlife Service. The Initiative involves two activities: conducting targeted research to enhance the effectiveness of fish habitat restoration projects, and implementing a vigorous information-transfer program to provide technical results to those who plan and carry out restoration projects. The Initiative began in summer 2002. It is being carried out by Montana State University biologists in collaboration with several private- and public-agency biologists. The Initiative includes five projects, each of which is described briefly below.

Technology Transfer. In recent years, many fish habitat enhancement and restoration techniques have been implemented; however, project results have not been shared widely and their efficacy is not well understood. To address this problem, we are compiling case histories of fish habitat restoration projects completed within the intermountain west (Idaho, Montana, Nevada, Wyoming, Utah, Colorado, eastern Washington, eastern Oregon, and eastern California). Project information includes narrative descriptions, project goals, restoration methods, project costs, landowner contributions, and monitoring data. Our intention is to provide useful information that will enable landowners and resource managers to make informed decisions regarding various fish habitat restoration techniques. The website was mounted in November 2002, and the database of case histories is growing. You can access progress at http://water.montana.edu/wildfish/.

Thermal Requirements of Westslope Cutthroat Trout. One of the most important fish-habitat attributes addressed in a restoration project is the thermal regime. If a restored habitat does not provide water of the right temperatures, fish cannot thrive and reproduce. This project defines the thermal tolerances of westslope cutthroat trout (*Oncorhynchus clarki lewisi*) so that they can be introduced with confidence following habitat-restoration projects in the northwestern US. The project uses testing facilities that were funded by a private consortium designed specifically for this purpose and housed within the USFWS Fish Technology Center at Bozeman, Montana.

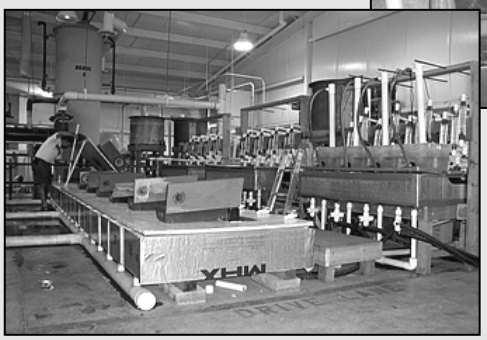
Irrigation Diversions. Irrigation diversions are often responsible for the loss of wild fish on agricultural lands. In many instances these losses may be preventable, with the proper screening devices. But the fundamentals of this approach - successful fish-passage configurations, maintenance requirements, conditions of use, and cost - are not well defined. In this project, before-and-after field studies are evaluating fish protection structures on private irrigated lands. The purpose is to generate well-documented case histories at representative sites that can be applied to projects in many other agricultural locations. The investigators work with private landowners and the Montana Department of Fish, Wildlife and Parks on Skalkaho Creek in the Bitterroot Valley of western Montana.

Bacterial Coldwater Disease. In much of the Northwest, westslope cutthroat trout are the native non-anadromous salmonid and the first choice for reintroduction into natural habitat restoration projects. However, this final restoration step often cannot occur, because fish free of bacterial coldwater disease are not available. Therefore, investigators are evaluating control measures for coldwater disease in westslope cutthroat trout. Montana Fish, Wildlife and Parks' Washoe Hatchery is the project site, which is designated for the rearing of cutthroats for reintroduction in the wild. The ultimate goal is effective disease control allowing for successful reintroduction of westslope cutthroat trout.

East Gallatin River Restoration Project. The East Gallatin River has a long history of impacts from agriculture and urban development. Currently this river is listed on the Montana Department of Environmental Quality's 303(d) list of impaired water bodies due to increased sedimentation. Bank stabilization procedures are often implemented to reduce this problem and control natural movements of the river. The East Gallatin River Restoration Project is constructing a demonstration project along the river using innovative bank stabilization approaches. This project is a cooperative effort of land owners, Montana Fish, Wildlife and Parks, the Montana Water Center, and the U.S. Fish and Wildlife Service Partners for Fish and Wildlife Program.

WILD TROUT RESEARCH LAB

In summer 2003, the Wild Trout Research Lab had the highest occupancy since its doors first opened in 1997. The lab provided space to large-scale Montana Fish, Wildlife, and Parks whirling disease exposure experiments. Fish exposed in streams throughout western Montana were held in the lab for three months to let whirling disease develop if present. The largest project came from Yellowstone National Park where fish from sentinel cages placed in tributaries to Yellowstone Lake occupied about half of the lab's capacity. To provide researchers with whirling disease parasite spores, the lab also maintained a supply of WD-positive fish available to scientists at no charge.



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